6. ICHTHYOPLANKTON AND FISH

REVIEW OF LITERATURE

Fisheries research in the Gunpowder River and adjacent waters of upper Chesapeake Bay has been reported only recently. The Chesapeake Biological Laboratory conducted a general biological survey of the Patapsco River with specific reference to Baltimore Harbor in 1970-71. Fish egg and larvae samples were collected at 12 stations in the Patapsco River and major tributaries, and beach seining was carried out at 17 stations during the sampling period of 1 year starting with March 1970 (Dovel, 1971a).

Distributions of adult fishes are described by Wiley (1971) in the above-mentioned biological study of Baltimore Harbor. Of particular interest is the apparent contradiction in the near total absence of bottom fishes (especially as compared to similar trawl stations in the nearby Chester River) and the very large numbers of white perch, a fish somewhat epibenthic in its habitat.

White perch was the dominant species in both the harbor and in the Chester River control area. Wiley (1971) pointed out a difference in the age class composition of fish from the two rivers, citing the absence of young-of-the-year white perch from the Chester River stations in the period 6 July through 1 September. However, less frequent sampling between those dates (less than half the stations normally sampled), a disproportionate amount of sampling in the mouth, and almost no samples taken above mile 3 of the Chester River may have accounted for these results. Also noted was the higher incidence of infection of the lateralis system and deterioration of fin tissues in Baltimore Harbor over Chester River white perch, possibly a result of pollution stresses. In 1971 ichthyoplankton tows and seine hauls were made at several stations in a series of tows bracketing the entire Bush River on two dates: 11 July and 15 August 1971. This preliminary sampling effort was part of a consultants report (BioCon, 1971b) to the Baltimore Gas and Electric Company.

Recent fisheries research was conducted in the upper Chesapeake Bay with specific regard for the effects of overboard disposal of ship channel dredging spoil. Biweekly sampling of fish eggs and larvae (by ichthyoplankton net tows) and adults (by 40 foot otter trawl tows) in the upper bay from May 1966 to November 1968 yielded large amounts of basic background information pertaining to the nature and status of the fisheries populations of the upper Bay (Dovel, 1970; Ritchie, 1970). In his studies of eggs and larvae, Dovel grouped the fishes into freshwater, estuarine, and marine spawners, and described the general life habits of each of the three, giving examples of each. He also stressed the importance of the upper Bay from Poole's Island northward to Turkey Point as a nursery ground upon which depends the successful survival of many species of fish. This area of low salinity (0 to 11 ppt) is heavily used all or in part during virtually the entire year by one or more species as a spawning and/or nursery area for some 13 species of freshwater spawners, 13 species of estuarine spawners, and 11 species of marine spawners.

The effects of dredge spoil disposal on adult fish was investigated by Ritchie (1970). Forty-four species of fish (13 freshwater and 31 marine forms) were captured by trawling at 10 stations on 5 transects running perpendicular to the shipping channel in the upper Bay. The fishes were described as year-round residents (e.g., striped bass, white perch, channel catfish, hogchoker, yellow perch, alewife, bay anchovy, and blueback herring), seasonal migrants (e.g., spot, weakfish, silver perch, and bluefish) and irregular visitors (e.g., silver hake and northern sea robin).

Ritchie (1970) found white perch to be most numerous during most months, but also present in large numbers were striped bass, bay anchovies, channel catfish, hogchokers, and gizzard shad. On the basis of the trawl data, the upper Chesapeake Bay from Turkey Point south to Poole's Island supports a large diversity of fish species; some as year-around residents and some as seasonal visitors, either as part of a spawning migration or merely entering during the warm-water periods for feeding purposes. The greatest species diversity was observed at upstream, low salinity

stations. The seasonal changes in water temperature and salinity appeared to have the greatest effect on the species composition of his samples.

Dovel (1971b) summarized 10 years of fish egg and larvae sampling in the upper Chesapeake Bay, Magothy River, and Patuxent River and stressed the similarity of the freshwater/brackish water interface areas of each of these somewhat separated regions of the Chesapeake Bay system. This area of transition (ecotone) in each separate sampling region is important as a spawning area (for white perch, striped bass, and herrings – genus Alosa), and as a nursery area for fishes that have spawned in freshwater (yellow perch), brackish water (anchovy, hogchoker, naked goby, winter flounder), or in the marine environment (menhaden, croaker, spot, and bluefish). This ecotone also supports the resident forage species such as the top minnows (genus Fundulus) and the silversides (genus Menidia) which, in addition to the young of other species, provide a great bulk of the food for the game and commercially important species, most notably bluefish and striped bass (Dovel, 1971b). Dovel noted the greatest densities of zooplankton in the Patuxent to be coincidental in time and location with the developing larvae of the freshwater spawners and suggested this is significant in the transition of the larvae from yolk-sac absorption to active feeding.

Fishes that spawn in the estuary, such as the hogchoker and anchovy, do so over a large area of the estuary and under a wide range of temperatures and salinities. Eggs of the anchovy in the Patuxent River during 1963, for instance, were found at salinities ranging from 3 to 23 ppt, and the larvae, after moving toward fresher water, were found between salinities of 0 and 21 ppt (Dovel, 1971b). Likewise, the marine spawners, as larvae, during migrations to fresher water, obviously tolerate large salinity and temperature changes. The presence of larvae and/or juveniles of all three groups of spawners in the low saline areas (1 to 15 ppt) indicates the great importance of this area for normal growth and development of each of the species.

Although Dovel (1971b) feels that salinity is the dominating factor in the distribution of eggs and larvae in the upper Bay system, temperature is essential in stimulating the successful development of gonadal tissues and spawning behavior in adults, the normal development of the embryo and the resultant larvae. Of interest is the fact that larvae or juveniles of several estuarine-dependent species often winter-over in the very cold waters of the upper estuary, though the warmer, deeper waters further downstream are relatively close by.

The only published beach seine work near the Bush River area to date was done by Spier (1972) from May 1970 to January 1971. Twenty-four species of fish were collected with a 100 foot seine around Carroll Island. The results indicated that three species dominated the area – the bay anchovy, white perch, and tidewater silverside. White perch and silverside were present throughout the study period, but the bay anchovy was abundant only in September and October.

In summation of the present status of fisheries research, the upper Chesapeake Bay seems to be a typical example of a coastal plain estuary. In the upper Bay a relatively diverse fisheries population exists composed of at least 44 species as sampled by trawling. In addition, this area provides a spawning and/or nursery area for many fishes. Many of the species of fish found in the seining samples collected from the Gunpowder River are also present in the upper bay area and the Patapsco and Magothy Rivers.

METHODS AND MATERIALS

Several collecting methods are being employed monthly to sample fish in various stages of development from several habitats in the Bush River estuary.

Fish egg and larval populations are sampled by means of an 0.5 meter diameter plankton net (505 μm mesh) mounted on a steel frame sled towed for 15 minutes (as

described previously for zooplankton populations). Fish eggs and larvae collected are preserved in 4% formalin and identified to the species level where possible, and the specimens are then stored at The Johns Hopkins University for reference. Egg diameters and total lengths of larvae are measured (in mm) and recorded, and the latter will be used to establish length frequencies and growth curves with succeeding sampling dates.

A 50 x 6 foot beach seine is used to sample the resident fishes inhabiting the shore zone, young-of-the-year, and juveniles of fishes spawned in the area, or using the area as a nursery ground. The beach seine employed has a 0.75 inch stretch (0.375 inch bar) mesh in the wings and 0.5 inch stretch (0.25 bar) mesh in the bag. Beach seining is of necessity limited to rather smooth, snag-free areas less than 6 feet in depth and must be landed on a gently sloping beach surface to prevent fishes from escaping under the lead line. Seining is regularly performed at each of five stations in the Bush River (Stations 1, 2, 3, 4, and 10 in Fig. 1). Fishes collected by beach seine are identified to species, and the total lengths (in mm) of a representative number of specimens of a species (30 or 40) are recorded. This allows most fish to be released alive. However, rare species or unusual specimens are preserved for reference purposes.

Two types of trawls are used to sample the adult fishes. A 16 foot semi-balloon otter trawl with 1.5 inch stretch mesh in the body and a 1.25 inch stretch mesh in the cod end with a 0.5 inch stretch inner liner is employed to catch bottom-dwelling and epi-benthic fishes such as hogchokers, catfish, American eels, and white perch. D-traps were used in the preliminary study (July and August 1971) to catch these bottom-dwelling and epi-benthic species, but its use was discontinued in favor of the otter trawl with its higher catch rates. A 10 x 10 foot modified Cobb pelagic (mid-water) trawl of 0.75 inch stretch mesh in the body and 0.5 inch stretch mesh in the cod end is used to sample the pelagic fishes that inhabit the upper portions of the water column and to supplement the beach seine data. These

pelagic fishes are typified by the bay anchovy, herrings, menhaden, and other forage species. All trawls are of 10 minutes duration. Both types of trawls are used at each of the six stations in the Bush River (Stations 3, 6, 8, 9, 11, and 12 in Fig. 1). Fishes collected by both methods of trawling are identified to species with a representative number measured and the remainder counted and released as with the seined specimens. Occasionally, stomach contents are analyzed and conditions of gonads noted where pertinent. A routine comprehensive stomach analysis will be performed on several species later in the present study.

Ultimately, fisheries data will be punched onto computer cards for more complete and rapid analysis. Items to be examined include species composition at each station, percentage composition of the species population contributed by each year class, species distribution as affected by water temperatures, and dissolved oxygen concentration. Also to be considered is the species diversity at each station and at a particular station over a time interval which may reflect either temperature, salinity, or dissolved oxygen preferences, or changing behavior patterns.

RESULTS

Fishes of 38 species were taken in the Bush River area during the period March through December 1972 using all gear types. The scientific and common names after Bailey et al. (1970) of these 26 854 specimens represented as eggs, larvae, juveniles, and adults are summarized phylentically in Table 20. Also, each species is classified to indicate its spawning-salinity preference(s). This list includes 23 freshwater spawners, 2 freshwater or estuarine spawners, 7 estuarine spawners, and 6 marine spawners.

Ichthyoplankton samples from seven stations over a 10 month period yielded a total of 5638 eggs, larvae, and juveniles of 9 species and 1 family that possibly represents an additional 5 species. Some larvae of the herring family were readily identifiable, but size range overlap, similar

		egg	larvae	juvenile	adult
FAMILY					
Anguillidae - freshwater eels					
Anguilla rostrata (Lesueur) American eel	M			X	X
Clupeidae - herrings			X		
Alosa aestivalis (Mitchill) Blueback herring	F			X	X
Alosa pseudoharengus (Wilson) Alewife	F			X	X
Alosa sapidissima (Wilson) American shad	F			X	
Brevoortia tyrannus (Latrobe) Atlantic menhaden	M			X	X
Dorosoma cepedianum (Lesueur) Gizzard shad	F				
Engraulidae - anchovies					
Anchoa mitchilli (Valenciennes) Bay anchovy	E		X	X	X
Cyprinidae - minnows and carps					
Carassius auratus (Linnaeus) Goldfish	F				X
Cyprinus carpio Linnaeus Carp	F		X		X
Hybognathus nuchalis Agassiz Silvery minnow	F				X
Notemigonus crysoleucas (Mitchill) Golden shiner	F				X
Notropis hudsonius (Clinton) Spottail shiner	F			X	X
Notropis sp. Shiner	F		X	X	X
Ictaluridae - freshwater catfishes					
Ictalurus catus (Linnaeus) White catfish	F			X	X
Ictalurus nebulosus (Lesueur) Brown bullhead	F			X	X
Ictalurus punctatus (Rafinesque) Channel catfish	F			X	X
Belonidae - needlefishes					
Strongylura marina (Walbaum) Atlantic needlefish	F				X
Cyprinodontidae - killifishes					
Fundulus diaphanus(Lesueur) Banded killifish	F-E				X
Fundulus heteroclitus (Linnaeus) Mummichog	E				X
Atherinidae - silversides				X	
Menidia beryllina (Cope) Tidewater silversides	E				X
Menidia menidia (Linnaeus) Atlantic silversides	E				
Percichthyidae - temperate basses					
Morone americana (Gmelin) White perch	F	X	X	X	X
Morone saxatilis (Walbaum) Striped bass	F-E	X	X	X	X
Centrarchidae - sunfishes					
Lepomis cyanellus Rafinesque Green sunfish	F				X
Lepomis gibbosus (Linnaeus) Pumpkinseed	F				X
Lepomis macrochirus Rafinesque Bluegill	F				X
Lepomis megalotis (Rafinesque) Longear sunfish	F				X
Micropterus dolomieui Lacépède Smallmouth bass	F			X	
Pomoxis annularis Rafinesque White crappie	F				X
Pomoxis nigromaculatus (Lesueur) Black crappie	F				X
Percidae - perches					
Ethepstoma nigrum Rafinesque Johnny darter	F				X
Perca flavescens (Mitchill) Yellow perch	F		X	X	X
Pomatomidae - bluefishes					
Pomatomus saltatrix (Linnaeus) Bluefish	M			X	
Sciaenidae - drums					
Cynoscion nebulosus (Cuvier) Weakfish	M			X	
Leiostomus xanthurus Lacépède Norfolk spot	M			X	
Micropogon undulatus (Linnaeus)Atlantic croaker	M			X	
Gobiidae - gobies					
Gobiosoma bosci (Lacépède) Naked goby	E		X		
Soleidae - soles					
Trinectes maculatus (Block and Schneider) Hogchoker	E				X

TABLE 20 SCIENTIFIC AND COMMON NAMES OF FISHES, EGG, LARVAE, JUVENILE AND ADULT FORMS COLLECTED FROM THE BUSH RIVER STUDY AREA, MARCH – DECEMBER, 1972. SPAWNING TYPES: F = FRESHWATER, E – ESTUARINE; M = MARINE

morphological indices, and various degrees of mutilation prohibited positive identification of the majority. Thus, a few Alosa sp., gizzard shad, menhaden larvae were grouped together with the other undifferentiated herring larvae. Table 21 presents a breakdown of numbers of a life stage, percent occurrence, and months collected for the various species to the left; on the right is a summary of stations where each life stage was collected. The total number of each life stage collected, percent occurrence, and the relative abundance figures presented in Table 22 are somewhat biased because of selectivity of the gear for smaller fish. Identification to species of the one mutilated shiner (Notropis) larvae was impossible.

A total of 4990 fish of 31 species was collected with the beach seine from May through December 1972 at five stations during eight sampling periods. The data from these 40 samples are summarized in Table 23.

The relative abundance figures given in Tables 23 through 25 present a more reliable estimate of the percentage composition each species contributes to the total. Many of these species are schooling fish; thus, sampling figures can be extremely high or low. Converting the total numbers to relative abundance figures will diminish the extremes, such as the bay anchovy figures in Table 25.

A total of 11 017 fish of 25 species were caught with the otter trawl at six stations from May through December 1972 during eight sampling periods. The 48 samples are summarized in Table 23.

The Cobb trawl caught 5209 fish of 22 species from May through December 1972 during seven sampling periods at six stations. These data are summarized in Table 25.

The species occurrence by numbers at all of the Cobb trawl, otter trawl, and beach seine stations for May through December is in Tables 26 through 33. The total catch per station per month by gear is also included.

Fish	Lifestages	Total	Months collected	Stations						
				1	3	6	8	9	11	12
Herring	larvae	372	Apr-Aug		X		X	X	X	X
	juveniles	8	Jul-Aug							
Bay anchovy	larvae	11	Aug-Sep		X	X		X		X
	juveniles	10	Sep-Nov			X	X	X		
Carp	larvae	4	Jul				X	X		
Shiner	larvae	1	Jul					X		
American eel	juveniles	1	May			X				
White perch	egg	20	Apr-May	X			X			X
	larvae	2412	May-Jul	X	X	X	X	X	X	X
Striped bass	egg	2137	May					X		
	larvae	14	Jun-Jul		X	X		X	X	X
	juveniles	2	Jul-Aug			X		X		
Yellow perch	larvae	506	Apr-May		X	X	X	X		X
Silverside	larvae	69	Jun&Aug			X	X	X	X	X
Naked goby	larvae	48	Aug-Sep			X		X		X

TABLE 21 SUMMARY OF 67 ICHTHYOPLANKTON TOWS FROM MARCH-DECEMBER, GIVING THE FISH LIFESTAGES COLLECTED, TOTAL NUMBERS, MONTHS COLLECTED, AND STATIONS

SPECIES		MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
Herring*	larvae	N	1.23 , 3 1.2 - 1.3	5.71 , 96 4.3 - 10.0	6.62 , 56 4.1 - 13.2	9.93 , 212 4.8 - 27.1	10.83 , 7 7.0 - 22.0			
	juvenile	O				30.72 , 6 29.1-32.4	30.1 , 2 27.2-31.7			
Bay anchovy	larvae	N					17.63 , 3 16.3-18.5	15.81 , 8 13.6-19.1		
	juvenile	J						24.1 , 3 23.0-25.3	38.8 , 5 34.0-44.0	32.0 , 2 31.0-33.0
Carp	larvae					6.63 , 4 4.9 - 7.8				
Shiner**	larvae					4.3 , 1				
American eel	juvenile	C		58.0 , 1						
White perch	egg	O	0.9 , 1	0.85 , 19 0.7 - 1.2						
	larvae	L		4.20, 2080 3.2 - 8.6	4.87 , 20 3.3 - 17.6	5.05, 312 3.2 - 14.2				
Striped bass	egg	L		3.21, 2137 2.70-3.69						
	larvae	E			7.9 , 1	7.56 , 13 5.2 - 13.4				
	juvenile	C				25.1 , 1	21.1 , 1			
Yellow perch	larvae	L	5.83 , 21 5.3 - 6.2	6.72, 506 7.4 - 13.2						
Silverside	larvae	E			5.92 , 29 5.3 - 8.9		5.34 , 40 4.6 - 8.6			
Naked goby	larvae	D					7.53 , 40 3.3-10.9	6.50 , 8 4.5 - 8.1		

*This could include blueback, alewife, American shad, Atlantic menhaden, and gizzard shad.

**These are any one or a combination of the following species: golden shiner, spottail shiner, or shiney minnow.

TABLE 22 RESULTS OF ICHTHYOPLANKTON SAMPLING IN THE BUSH RIVER, 10 MARCH 72 THROUGH 9 DECEMBER 72, SHOWING FISHES CAUGHT, LIFE STAGE, MEAN SIZE, NUMBER CAUGHT, AND RANGE

Fish	Total	% occurrence	relative abun.*
White perch	1617	77.5	1253.18
Spottail shiner	591	65.0	384.15
Gizzard shad	744	37.5	279.00
Blueback herring	522	32.5	169.65
Bay anchovy	498	32.5	161.85
Tidewater silverside	310	40.0	124.00
Atlantic menhaden	209	30.0	62.70
Golden shiner	84	35.0	29.40
Shiner species	128	20.0	25.60
Pumpkinseed	41	40.0	16.40
Yellow perch	28	40.0	11.20
Alewife	21	50.0	10.50
Johnny darter	38	27.5	10.45
Striped bass	47	17.5	8.23
Banded killifish	24	15.0	3.60
Silvery minnow	26	12.5	3.25
Atlantic silverside	27	5.0	1.35
Bluegill	8	10.0	0.80
Atlantic needlefish	7	10.0	0.70
Mummichog	12	5.0	0.60
White crappie	5	7.5	0.38
Bluefish	3	12.5	0.38
American eel	3	7.5	0.23
Carp	2	5.0	0.10
Black crappie	2	5.0	0.10
Longear sunfish	2	2.5	0.05
American shad	1	2.5	0.03
Goldfish	1	2.5	0.03
Channel catfish	1	2.5	0.03
Green sunfish	1	2.5	0.03
Smallmouth bass	1	2.5	0.03
Total: 31 species			

*Relative abundance = total number $\times \frac{\text{number of occurrences}}{\text{total no. of samples}}$

TABLE 23 TOTAL AND RELATIVE ABUNDANCE OF FISH IN 40 BEACH SEINE SAMPLES AT 5 STATIONS FROM THE BUSH RIVER AREA (MAY THROUGH DECEMBER)

Fish	Total	% occurrence	Relative abun.*
White perch	8397	93.75	7872.19
Bay anchovy	1429	33.33	476.33
Yellow perch	212	58.33	123.67
American eel	169	37.50	63.38
Spottail shiner	128	41.66	53.33
Hogchoker	140	31.25	43.75
Brown bullhead	104	41.66	43.33
Pumpkinseed	69	41.66	28.75
Channel catfish	74	33.33	24.66
Norfolk spot	101	14.58	14.73
Atlantic menhaden	50	22.92	11.46
Striped bass	26	18.75	4.88
Johnny darter	20	20.83	4.17
Alewife	28	10.42	2.92
Atlantic croaker	17	12.50	2.13
Blueback herring	20	10.42	2.08
White catfish	11	8.33	0.92
Bluefish	7	8.33	0.58
Gizzard shad	6	8.33	0.50
Carp	4	8.33	0.33
Alosa species	1	2.08	0.02
Golden shiner	1	2.08	0.02
Shiner species	1	2.08	0.02
Atlantic needlefish	1	2.08	0.02
Spotted seatrout	1	2.08	0.02
Total: 25 species			

*Relative abundance = total number $\times \frac{\text{number of occurrences}}{\text{total no. of samples}}$

TABLE 24 TOTAL AND RELATIVE ABUNDANCE OF FISH IN 48 OTTER TRAWL SAMPLES AT 6 STATIONS FROM THE BUSH RIVER AREA (MAY THROUGH DECEMBER)

Fish	Total	% occurrence	Relative abun.*
Bay anchovy	4033	52.38	2112.49
White perch	495	73.81	365.36
Atlantic menhaden	207	40.48	83.79
Blueback herring	136	23.81	32.38
American shad	128	9.52	12.19
American eel	37	28.57	10.57
Spottail shiner	23	16.66	3.83
Yellow perch	11	23.81	2.62
Hogchoker	9	19.05	1.71
Gizzard shad	13	9.52	1.24
Channel catfish	9	11.90	1.07
Pumpkinseed	6	16.66	0.99
Johnny darter	6	11.90	0.71
Alewife	9	7.14	0.64
Brown bullhead	6	9.52	0.57
Norfolk spot	11	4.76	0.52
Silvery minnow	2	4.76	0.095
Shiner species	2	4.76	0.095
Carp	2	2.38	0.048
Striped bass	2	2.38	0.048
Golden shiner	1	2.38	0.024
Atlantic croaker	1	2.38	0.024
Total: 22 species			

*Relative abundance = total number x $\frac{\text{number of occurrences}}{\text{total no. of samples}}$

TABLE 25 TOTAL AND RELATIVE ABUNDANCE OF FISH IN 42 COBB TRAWL SAMPLES AT 6 STATIONS FROM THE BUSH RIVER AREA (MAY THROUGH DECEMBER)

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring		1	6			8												15
Alewife																		
American shad																		
Alosa sp.																		
Atlantic menhaden																		
Gizzard shad	4	3	8			5		1					1					22
Bay anchovy			1										59					60
Goldfish													1					
Carp																		
Silvery minnow																		
Golden shiner	1	5	2			18												26
Spottail shiner	1	5	8		1	61							3					79
Shiner sp.		3				6							1					10
White catfish																		
Brown bullhead					4			2		3		1					4	14
Channel catfish					1								1					2
American eel		1			12			16				7	1				7	44
Atlantic needlefish																		
Banded killifish																		
Mummichog																		
Striped killifish																		
White perch	28	28	6		291	66		312		64		331					952	1999
Striped bass					1							2					1	4
Green sunfish																		
Pumpkinseed					8	1		3									4	16
Bluegill																		
Longear sunfish																		
Smallmouth bass																		
White crappie	1																	1
Black crappie																		
Johnny darter		2	1		2													5
Yellow perch		1			11	2		17					1					32
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker																	2	2
Tidewater silverside																		
Atlantic silverside																		
Hogchoker					2			4				20					46	72
Total no./sample	35	49	32	0	333	167	0	355	0	67	0	361	67	0	0	0	1016	

NOT SAMPLED

TABLE 26 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR MAY 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring	78	2	71		2	98	2						106	4		85	1	449
Alewife																		
American shad																		
Alosa sp.																		
Atlantic menhaden	1		1		12			4										18
Gizzard shad	2				1													3
Bay anchovy	14		51		34	2	3	5	3	8			26				89	235
Goldfish																		
Carp	1																	1
Silvery minnow																		
Golden shiner	5	1																6
Spottail shiner					45	5	1	14		5					5			75
Shiner sp.	9	1	7											1				18
White catfish															3			3
Brown bullhead							2	9		4								15
Channel catfish																		
American eel	1			3	5		6	9		5		5		1				35
Atlantic needlefish																		
Banded killifish																		
Mummichog																		
Striped killifish																		
White perch	20	2	68	17	360	7	9	400		324	2	1455	3	13	74	1	9	2764
Striped bass					1							5			2			8
Green sunfish																		
Pumpkinseed	6				1			2	1	1				2	6			19
Bluegill	1																	1
Longear sunfish	2																	2
Smallmouth bass																		
White crappie	2																	2
Black crappie																		
Johnny darter			1															1
Yellow perch		1			4			10		2			1		1		1	20
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker					2		1	1		5								9
Tidewater silverside			7			3							60					70
Atlantic silverside																		
Hogchoker									1									1
Total no./sample	348	7	206	20	467	115	24	454	5	354	2	1465	196	21	91	86	100	

TABLE 27 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR JUNE 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring			10	1												1		12
Alewife			10															10
American shad																		
Alosa sp.																		
Atlantic menhaden	58	5	11	106	3	22	28		1					12		28		274
Gizzard shad																		
Bay anchovy							1											1
Goldfish																		
Carp																		
Silvery minnow																		
Golden shiner					1									1				2
Spottail shiner			3		2	1				6				4				16
Shiner sp.		5																5
White catfish																		
Brown bullhead								8		4		6	NONE	1	18		7	44
Channel catfish					5					1					4		1	11
American eel				1				2	1		2	15		12	72	1	2	108
Atlantic needlefish			1															1
Banded killifish	1																	1
Mummichog																		
Striped killifish																		
White perch	6	1		7	176	4	10	180	6	76	2	91		19	174	1	101	854
Striped bass						1												1
Green sunfish																		
Pumpkinseed	2	1							1	7		1			12		7	31
Bluegill																		
Longear sunfish																		
Smallmouth bass																		
White crappie																		
Black crappie																		
Johnny darter					1													1
Yellow perch	1			1	25		1	1							8		2	39
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker																		
Tidewater silverside																		
Atlantic silverside																		
Hogchoker																		
Total no./sample	68	12	35	116	213	28	40	191	9	94	4	113	0	49	288	31	120	

TABLE 28 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR JULY 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring	19	11	1	7	1				1									40
Alewife			4															4
American shad							16		3							108		127
Alosa sp.																		
Atlantic menhaden	2	96	1	11	4		1	2	2		3							122
Gizzard shad		23	417			203												643
Bay anchovy							4		8		15					18		45
Goldfish																		
Carp				1						1								2
Silvery minnow																		
Golden shiner																		
Spottail shiner	10	4	18		4	2	3	5		2		2	2	1	2			55
Shiner sp.						1												1
White catfish								1				6						7
Brown bullhead				3	16							4						23
Channel catfish									3	4	1	14						22
American eel				6	1			1			1	2		1			1	13
Atlantic needlefish						1							1				1	3
Banded killifish	1					1												2
Mummichog																		
Striped killifish																		
White perch	20	3	10	26	265		28	299	2	41	9	640	5	37	314	2	110	1756
Striped bass	1		3									2						6
Green sunfish	1													1	2		2	1
Pumpkinseed	1		1	1	1	1												10
Bluegill																		
Longear sunfish																		
Smallmouth bass																		
White crappie																		
Black crappie																		
Johnny darter				3	2					2								7
Yellow perch			1	1	8			7		2					5	1	3	28
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker										1		4						5
Tidewater silverside			3			3							6					12
Atlantic silverside													18					18
Hogchoker												8		2	5			15
Total no./sample	55	137	459	59	302	212	52	315	19	53	29	682	32	42	328	129	117	

TABLE 29 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR AUGUST 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring		111	2	21	11		8	5	6									164
Alewife		2	2	5	3			7	1	6	2		3					31
American shad																		
Alosa sp.																		
Atlantic menhaden				7	2		1	2	1			1	10					24
Gizzard shad	31	11	32	2		1												77
Bay anchovy	24	5	10	343	739	11	437	109	404	46	1962	47	141	239	6	15	79	4781
Goldfish										1								1
Carp																		
Silvery minnow																		
Golden shiner		1	26															27
Spottail shiner	10	35	6			2		1		1								55
Shiner sp.	10	32	53	1														96
White catfish																		
Brown bullhead								1				1						2
Channel catfish										10		1						11
American eel												3						3
Atlantic needlefish						1							1					2
Banded killifish																		
Mummichog		1																1
Striped killifish																		
White perch	26	51	115	8	23	4	2	33		156		47	1		5		4	475
Striped bass			3									9						12
Green sunfish	1																	1
Pumpkinseed	1	3	2															6
Bluegill																		
Longear sunfish																		
Smallmouth bass																		
White crappie																		
Black crappie																		
Johnny darter		1			2		1											4
Yellow perch		5			4												2	11
Bluefish	1									2		1						4
Spotted seatrout																		
Norfolk spot				9	6		2	59		3		19			7		5	110
Atlantic croaker																		
Tidewater silverside	5	24	9			45							39					122
Atlantic silverside																		
Hogchoker								1				30		1	2			34
Total no./sample	109	282	260	396	790	64	451	218	412	225	1964	159	195	240	20	15	90	

TABLE 30 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR SEPTEMBER 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring										1								1
Alewife										9	1				3			13
American shad			1															1
Alosa sp.																		
Atlantic menhaden	1		1	1				11	1	10	2							27
Gizzard shad			2															2
Bay anchovy	148	2		88	19	4	14	99	190	80	281			3	7		61	996
Goldfish										1								1
Carp																		
Silvery minnow																		1
Golden shiner	1																	
Spottail shiner	30	56	69			198				4								357
Shiner sp.						5												5
White catfish												1						1
Brown bullhead															2			2
Channel catfish					2					1		8						11
American eel												3						3
Atlantic needlefish																		
Banded killifish	2	18																20
Mummichog		11																11
Striped killifish																		
White perch	12	1072	18		85	10	3	38		110	3	61	19		104			1535
Striped bass			9			1				3			25					38
Green sunfish																		
Pumpkinseed	6	3	2							1					1			13
Bluegill																		
Longear sunfish																		
Smallmouth bass																		
White crappie																		
Black crappie																		
Johnny darter	3	21	2			2						2						30
Yellow perch	1		1			1		1										4
Bluefish												1						1
Spotted seatrout												2						2
Norfolk spot												2						2
Atlantic croaker																		
Tidewater silverside	1	1	56			37							9					104
Atlantic silverside													9					9
Hogchoker					1							10						11
Total no./sample	205	1184	161	89	107	258	17	149	191	220	287	90	62	3	117	0	61	

TABLE 31 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR OCTOBER 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring																		
Alewife									1									1
American shad																		
Alosa sp.							1				1							2
Atlantic menhaden				4					7	2								13
Gizzard shad				1				1	2					1				5
Bay anchovy																		
Goldfish										1								7
Carp		3	2	1														
Silvery minnow		3	1															4
Golden shiner	1	2	1	6	6		1	3										20
Spottail shiner																		
Shiner sp.																		
White catfish					3					3		1			1			8
Brown bullhead					1				1	15		4						21
Channel catfish				1						1								2
American eel																		
Atlantic needlefish																		
Banded killifish																		
Mummichog																		
Striped killifish		1	1	17	25		14	49	23	141	15	161			9			457
White perch									2									2
Striped bass																		
Green sunfish		1			3			2					1		1			8
Pumpkinseed																		
Bluegill																		
Longear sunfish																		
Smallmouth bass	2																	2
White crappie																		
Black crappie		4	1	1	1		1	2										10
Johnny darter		2	1	5	7			17		2		1		1	17		1	53
Yellow perch																		1
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker													2					2
Tidewater silverside																		
Atlantic silverside				1			1		3	2		6						13
Hogchoker																		
Total no./sample	3	16	7	37	46	0	18	74	39	167	16	173	3	2	28	0	1	

TABLE 32 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR NOVEMBER 1972

Station no.	1	2	3			4	6		8		9		10	11		12		TOTAL
Gear type	seine	seine	seine	Cobb	otter	seine	Cobb	otter	Cobb	otter	Cobb	otter	seine	Cobb	otter	Cobb	otter	
Blueback herring																		
Alewife																		
American shad																		
Alosa sp.																		
Atlantic menhaden				1														1
Gizzard shad	1	1	1	1	2													6
Bay anchovy																1		1
Goldfish																		
Carp		1						1										2
Silvery minnow	2	9	1	1		3												16
Golden shiner	9	11				5												25
Spottail shiner	1	45	9	1	18	3		1		1								79
Shiner sp.																		
White catfish																		
Brown oullhead				1	2													3
Channel catfish				1								2						3
American eel																		
Atlantic needlefish																		
Banded killifish		1																1
Mummichog																		
Striped killifish																		
White perch		3	4	30	93	3	14	51	2	6	13	150		2	1		6	378
Striped bass																		
Green sunfish																		
Pumpkinseed	1	6		1				4						4				16
Bluegill	3	3	1															7
Longear sunfish																		
Smallmouth bass	1																	1
White crappie																		
Black crappie	1	1																2
Johnny darter		3		1	5			1										10
Yellow perch		7	1	1	8	1	2	45	1			1		3	2			72
Bluefish																		
Spotted seatrout																		
Norfolk spot																		
Atlantic croaker																		
Tidewater silverside																		
Atlantic silverside																		
Hogchoker									2	1	2	2						7
Total no./sample	19	91	17	39	128	15	16	103	5	8	15	155	0	9	3	1	6	

TABLE 33 SPECIES OCCURRENCE BY NUMBERS AT STATIONS FOR DECEMBER 1972

DISCUSSION

The Bush River study area ichthyofauna is similar in some aspects to that of the adjacent Chesapeake Bay and different in other respects. In his studies of the upper Bay, Dovel (1971) found recently hatched stages of white perch, yellow perch, several species of herring, striped bass, and naked goby to be abundant in waters having salinities up to 13 ppt. These species are also present in the Bush River study area as indicated by Tables 22 and 23. Other larval forms also present in both the Bay and the Bush River include the bay anchovy and silverside. Only eggs of one species, the white perch, were found in the Bush and Gunpowder Rivers.

Some 2000 striped bass eggs were collected at Station 9 in the bay proper. Since no eggs were collected at any of the stations in the Bush or Gunpowder Rivers, there is probably little, if any, striped bass spawning in these rivers of low flow. The study area is adjacent to one of the major striped bass spawning areas in the Chesapeake Bay system, and is probably used by the larvae and juveniles (Dovel and Edmunds, 1971).

Carp larvae were found at Stations 8 and 9 (at the mouth of the Bush River and 400 yards out from the mouth of Romney Creek, respectively) though none had been found in the upper Chesapeake Bay by Dovel (1971). Carp usually spawn in freshwater, but they have also been reported to spawn in water exceeding 10 ppt (Mansueti and Hardy, 1967). The size range of these yolk-sac larvae would indicate that they were spawned nearby, rather than further upstream in the Bush River near Otter Creek or Church Creek as might have been expected.

The white perch larvae far outnumbered the other larvae in the present study, as they did in Dovel's (1971) fish egg and larvae study. In the present investigation, most of these larvae were still in the yolk-sac stage. As young juveniles grew, they became less available to the ichthyoplankton sampling gear. Also of interest was the

presence of white perch larvae (3 to 8 mm long) in July. The white perch spawning period normally occurs from March to June. This extension or delay of the spawning season might be due to the effects of tropical storm Agnes or more probably to the rather cool, wet spring that preceded Agnes.

Species composition of the present study compares favorably with the studies done by Ritchie (1970), BioCon (1971b), and Spier (1972). The different species composition of the four studies is due in part to gear selectivity.

Differences in the total number of species and species composition of otter trawl samples in the present study and those of Ritchie (1970) are due to any one or a combination of the following factors: (a) some of the fishes tend to avoid freshwater totally, and concentrate in waters of higher salinities such as in the channel areas of the upper Chesapeake Bay; (b) other species are rarely collected in the upper Chesapeake Bay (Atlantic sturgeon, butterfish, northern searobin, scaled carp, silver hake, southern harvestfish, spotted hake); and (c) the present study employed a 16 foot otter trawl for 8 months while Ritchie (1970) used a 40 feet otter trawl for 2 years.

A comparison of the number of species and species composition of the beach seining done by BioCon (1971), Spier (1972), and in the present study shows consistency of species composition and number of species with only few exceptions. These exceptions might be a reflection of the different lengths of beach seines used in the various studies, the time lengths of the studies, the scarcity of different species in the study area, or a combination of these factors. Another factor that may have contributed to differences in the four studies could be the effects of tropical storm Agnes. Tropical storm Agnes drastically lowered the salinity and water temperature of the entire Bay region in late June. This and other tremendous changes in water quality had a profound effect on fish distributions in the upper Chesapeake Bay. Some indication of the effect Agnes had on the upper bay may be seen when a comparison is made of Tables 26 through 30. A drastic reduction in the

numbers of almost all fishes collected in July samples is obvious, and is further substantiated by comparison of the mean numbers collected per haul by gear in July to the mean numbers per haul by gear for the period May through September. The mean number of fish collected per beach seine haul for all stations for the period May through September is 126.8, as compared to 28.6 in July. The otter trawl catch shows a comparable reduction. The mean number of fish collected per tow for the period May through September at all stations is 274.8, whereas for July it is 169.8. The trend continues with the Cobb trawl results as the mean number of fish per haul for May through September is 175.6, compared to the July figure of 41.5.

A notable exception is the American eel which increased in number. The pumpkinseed and yellow perch numbers remained fairly constant. A few of the other less numerous species show no significant patterns. The fishes showing the greatest reduction in numbers are those having affinities for slightly saline waters, i.e., blueback herring, white perch, bay anchovy, and striped bass. The yellow perch, American eel, and pumpkinseed tolerate low saline waters and the increased numbers may be a result of concentration into the waters where the otter trawl is more efficient, e.g. eels showed an increase from 34 in June to 108 in July. Considering the otter trawls for Stations 3, 6, 8, and 9, a reasonable average of six eels per tow was made compared to about 4.25 eels per tow at these same stations in July. Station 9 in July accounted for 88% of the total. An even bigger eel haul occurred at Station 11 in the Gunpowder River. Perhaps this concentration in the "deeper" water was due to a rich nutrient load which may have concentrated other food organisms.

No other researcher has used the Cobb trawl in the upper Chesapeake Bay; therefore, no comparisons can be made. To date, only the American shad has been collected by the Cobb trawl, but not by either the beach seine or the otter trawl. Compared to the otter trawl, the Cobb trawl seems to catch far fewer total numbers and fewer species of fish at the same stations even when the presence of clam shells indicates that the Cobb trawl had also sampled the

epi-benthic habitat as well as the pelagic areas. Possibly the finer mesh of the Cobb trawl is more readily detected and avoided by the fish. Continued collection with this trawl should help determine its usefulness in future work.

Monthly length frequencies for seven species of fish collected by all gears are given in Figs. 44 through 50. The large differences in length will separate the year classes of fishes, especially in the earlier years. With certain concessions, the size range, modal length, and growth curves of at least some of the year classes can be determined when examined over a period of time.

Examination of the length frequencies of white perch, the dominant species in the area (Fig. 44), shows that the monthly samples were made up up at least four year classes. The small numbers or lack of numbers in the 8 to 22 mm range during May through August is probably due to an increased ability to avoid the ichthyoplankton gear, as mentioned earlier. A very large reduction in numbers of the 3 to 7 mm range young-of-the-year occurred in June, but following tropical storm Agnes, increased numbers of this size range were again evident. This late spawn is unusual for this early spring spawners, and suggests that the spawning season was possibly extended by the change in water quality brought about by the cool, wet spring weather or by tropical storm Agnes. The young-of-the-year length frequencies implies a growth from about 5 mm in May to approximately 50 mm in September. From May through August the 1 year class seemed to grow approximately 50 mm in September. From May through August the 1 year class seemed to grow approximately 20 mm. The 2 year class sampled would seem to have grown only about 5 mm during the same 4 month period. The actual lengths of the 1 and 2 year class fish in September, November, and December are difficult to separate because of insufficient numbers and an overlap of size range.

Atlantic menhaden (Fig. 45) of the 0 year class (fish spawned in the fall of 1971) moved into the area from downbay. By July it appears both the spring and fall spawned 0 year class fish, and possibly those of 2 year also are

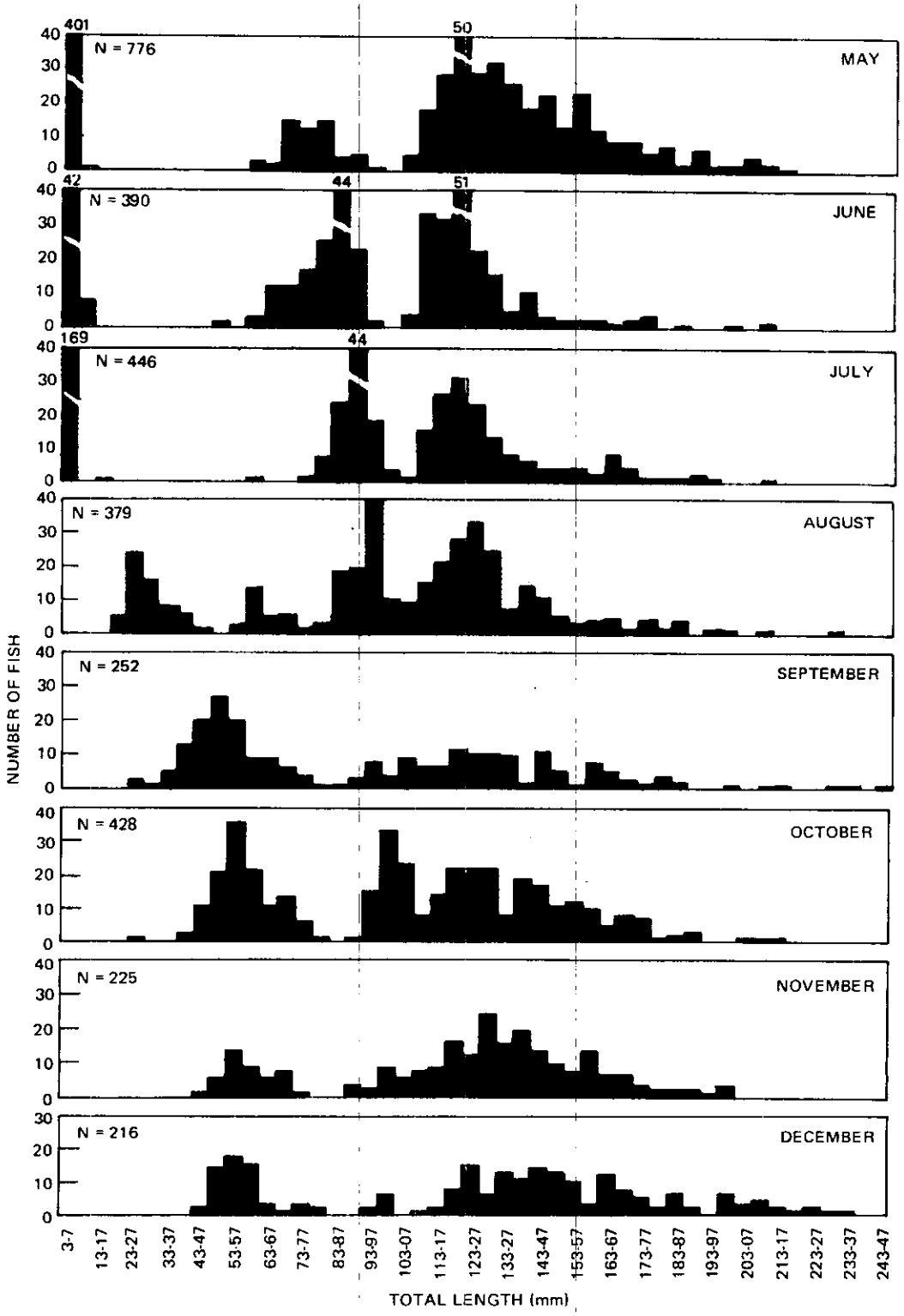

Fig. 44 MONTHLY LENGTH FREQUENCIES FOR WHITE PERCH COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

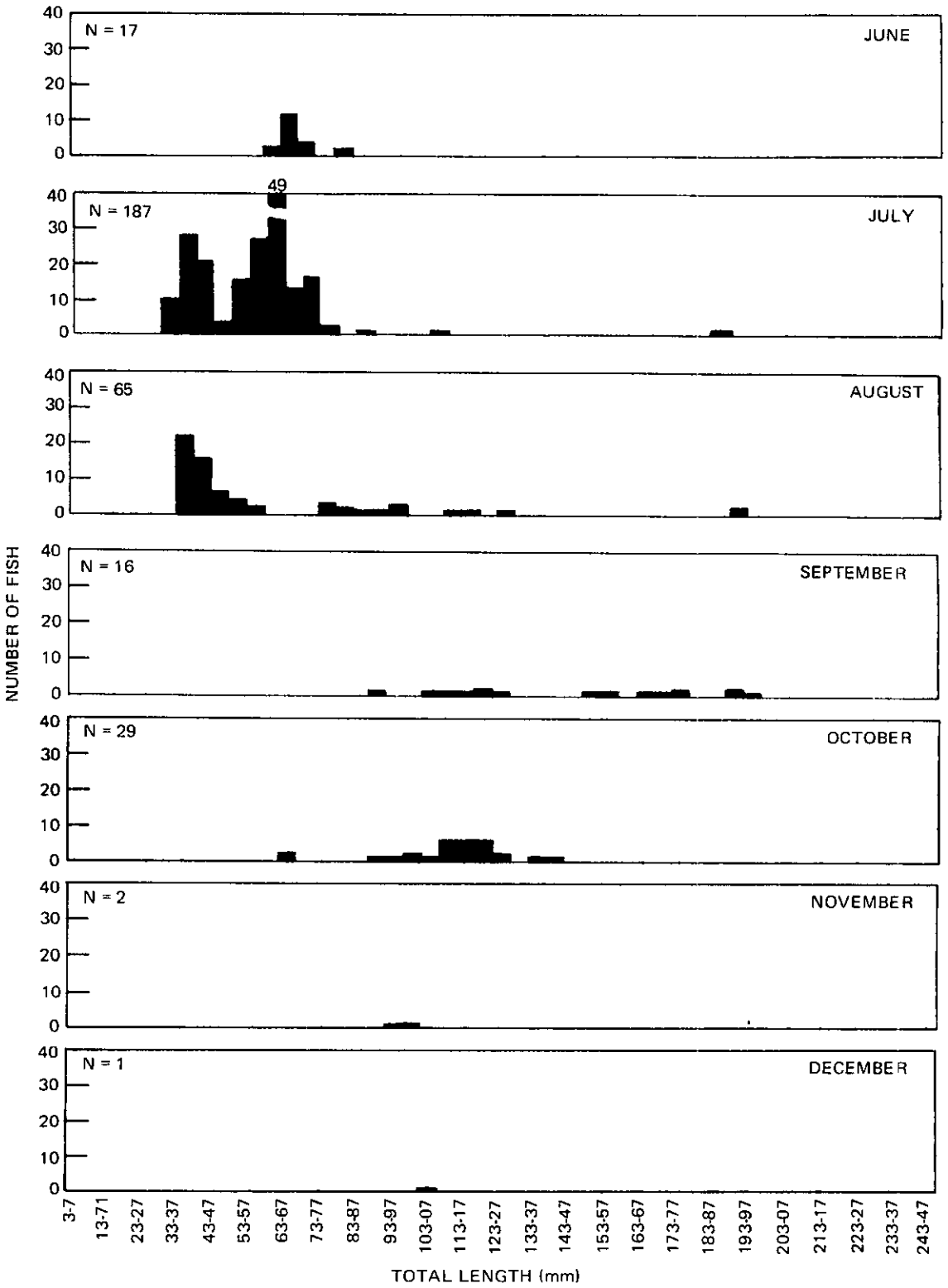

Fig. 45 MONTHLY LENGTH FREQUENCIES FOR ATLANTIC MENHADEN COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

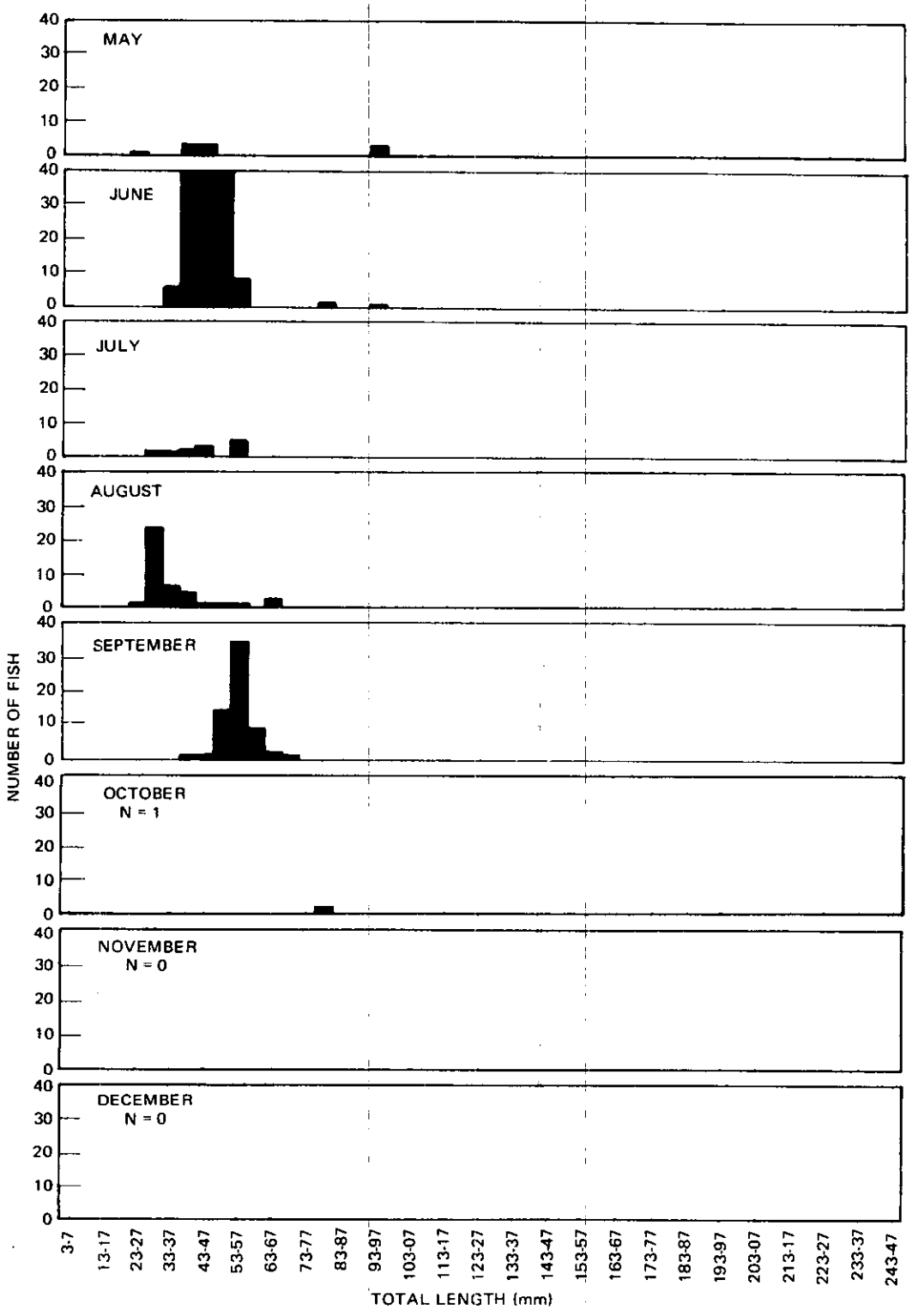

Fig. 46 MONTHLY LENGTH FREQUENCIES FOR BLUEBACK HERRING COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

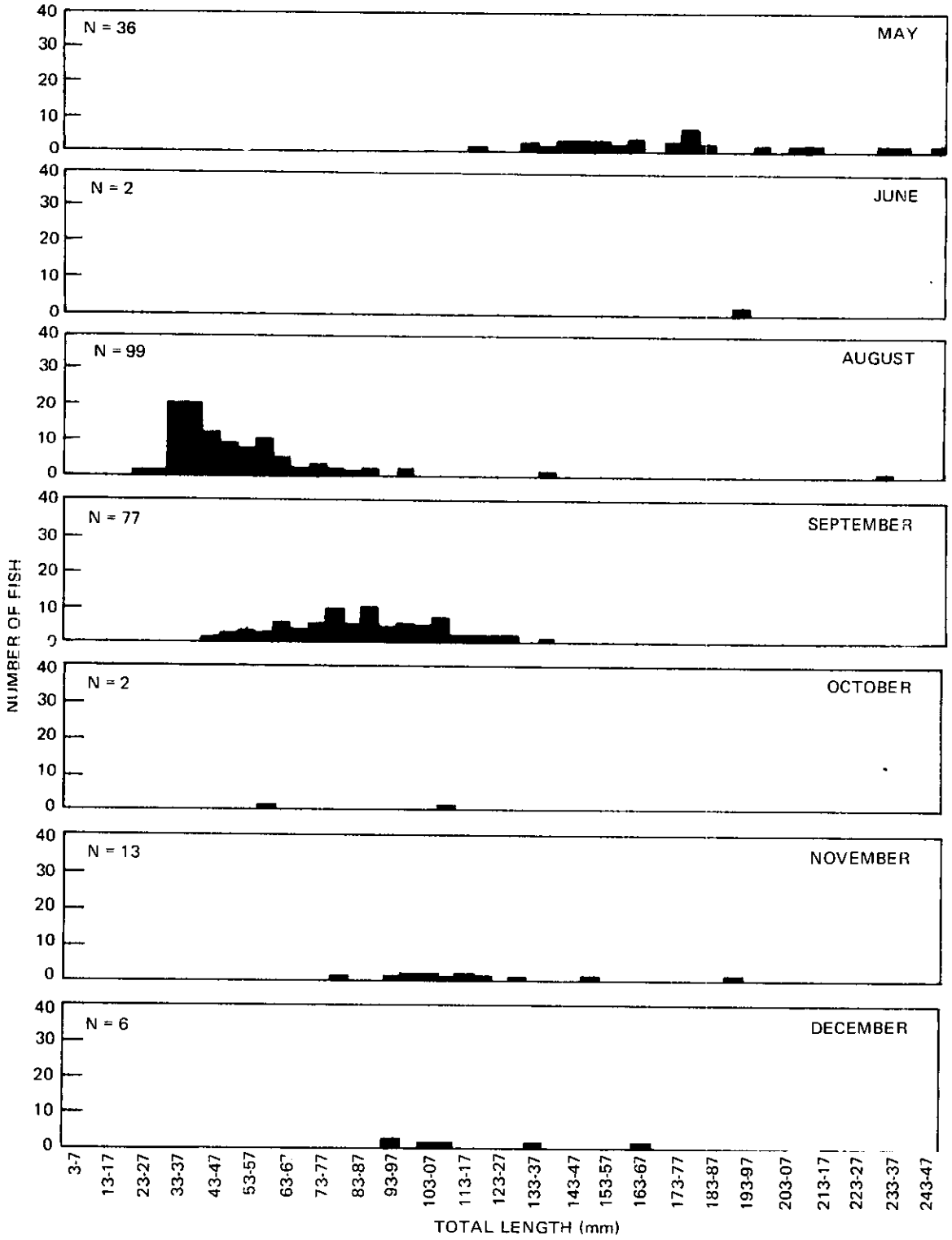

Fig. 47 MONTHLY LENGTH FREQUENCIES FOR GIZZARD SHAD COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

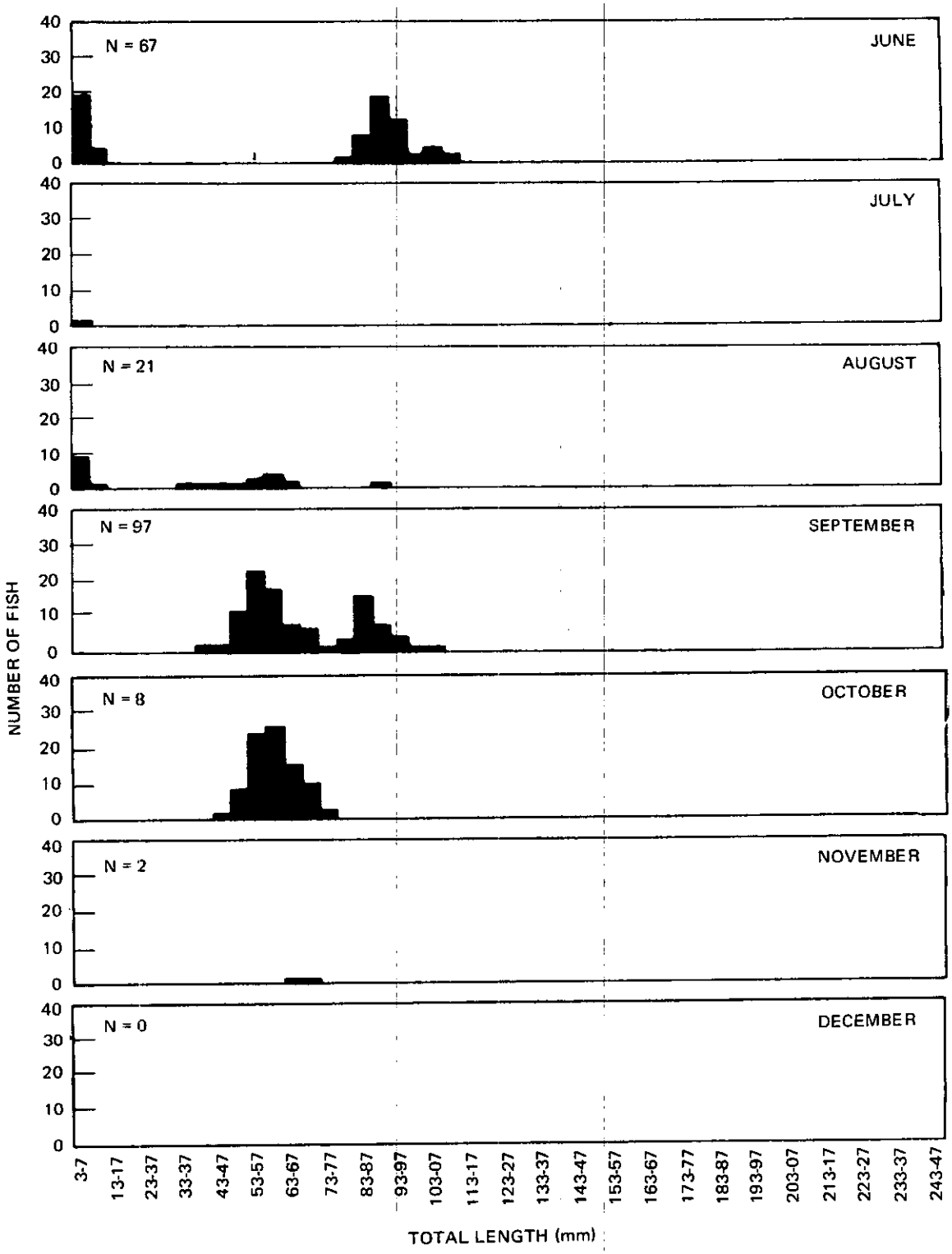

Fig. 48 MONTHLY LENGTH FREQUENCIES FOR TIDEWATER SILVERSIDE COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

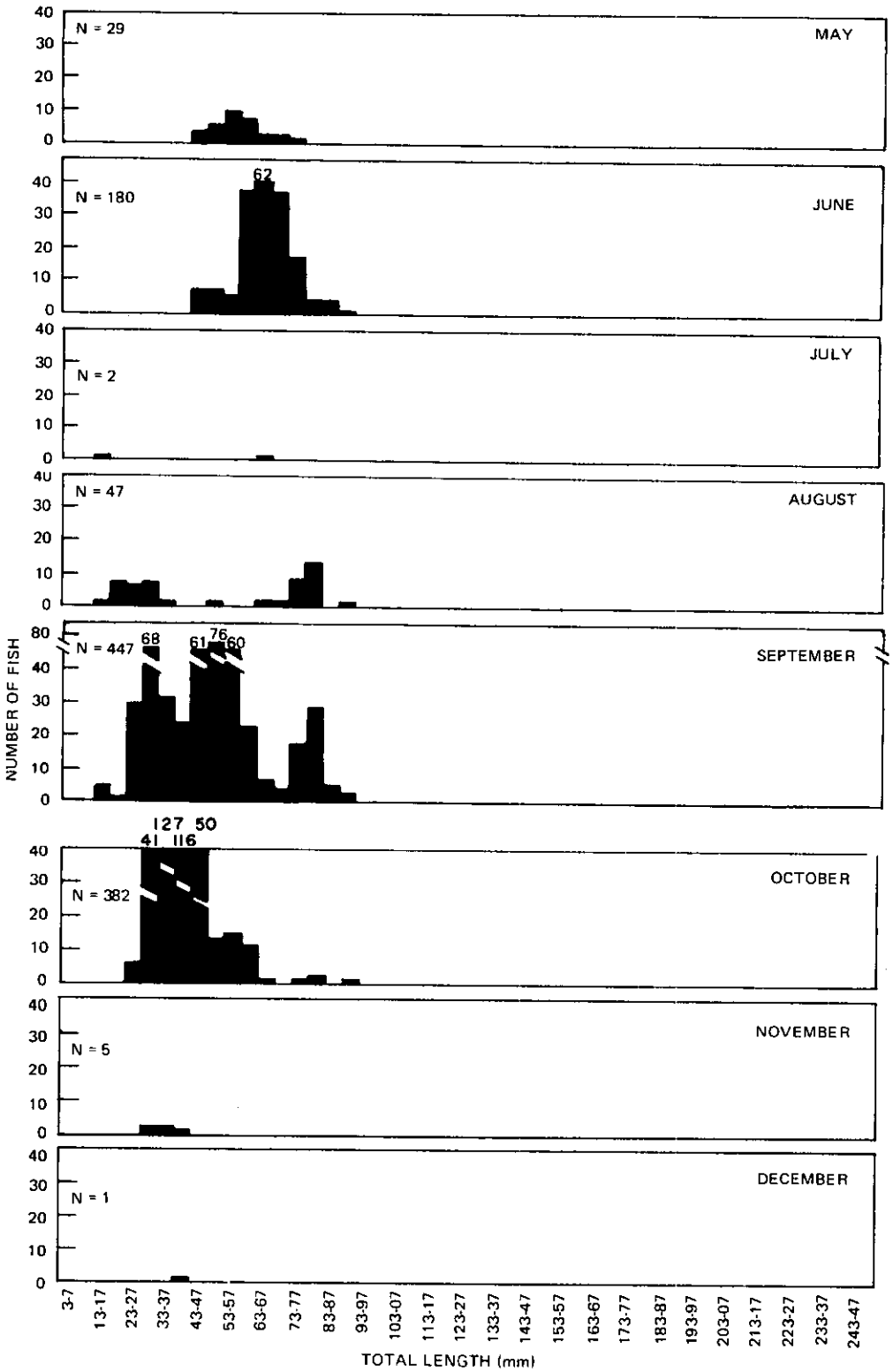

Fig. 49 MONTHLY LENGTH FREQUENCIES FOR BAY ANCHOVY COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

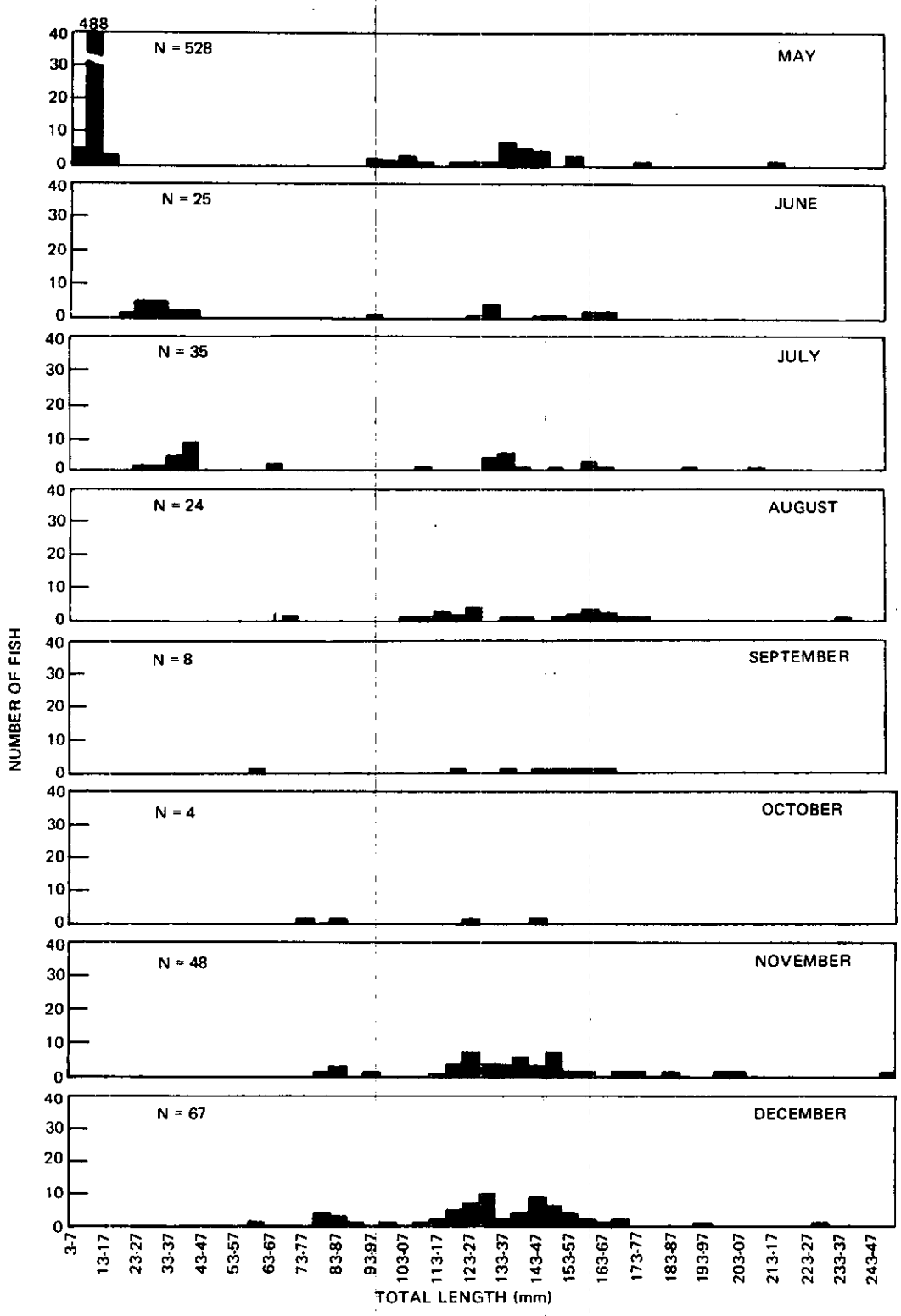

Fig. 50 MONTHLY LENGTH FREQUENICES FOR YELLOW PERCH COLLECTED BY ALL SAMPLING GEAR IN THE BUSH RIVER AREA, MAY THROUGH SEPTEMBER 1972

present. The September sample is made up of the fall spawned 0 year class which is almost 1 year old, and fish almost 2 years old. The fall samples for September through December show an ever-increasing decline in numbers as these fish move downbay; and such a decline is probably a result of fish leaving the sampling area rather than gear inefficiency.

Blueback herring length frequencies (Fig. 46) indicate the presence of juveniles from May through the October sampling period. The effects of tropical storm Agnes caused many of these fish to move from the area as shown by the reduced numbers in the July samples. This fluctuation in numbers as well as those later in the summer and fall could be nothing more than a reflection of the natural movements of this species in the upper bay.

Length frequencies of the gizzard shad (Fig. 47) show the presence of the 1 year, 2 year, and older classes of fish in the May and June samples. Young-of-the-year fish (ca. 35 to 40 mm) appeared in large numbers in the August and September samples mixed with large numbers of fish nearing the end of their first year (ca. 120 mm). Separating these first 2 year classes is difficult because of an overlap in size ranges resulting from a protracted spawning time in May through August (Mansueti and Hardy, 1967). During the fall months of October through December, a reduction in numbers occurs. This seems to follow the general pattern of movement to warmer, deeper water by most fish found in temperate waters.

Tidewater silversides (Fig. 48) are probably represented by three year classes in the June samples; the young-of-the-year and combined 1 and 2 year fish. As has been previously stated for other species, a large reduction in numbers occurred following tropical storm Agnes, with an eventual return of these fish in August and September. The fall sampling shows a sharp reduction in numbers from October to November with none collected in December. The reduction in numbers following Agnes and in the fall could again be attributed to the movement of the fish out of

the shore zone sampling area into the deeper water of the upper bay.

Bay anchovies had become somewhat numerous by the June samples, and length frequency data (Fig. 49) indicate the mean length to be near 65 mm. These fish are almost 1 year old, having been spawned during the summer of 1971. The decline in numbers during July and August might well reflect the effects of tropical storm Agnes. However, this may just show the general movement of this estuarine spawner toward the spawning areas in more saline waters (Dovel, 1971b). The July through October data show the presence of the 0 year class and 1 year class, with the bulk made up of the 0 year class in September and October. Again, a sharp reduction in numbers is repeated as the water temperature drops in the fall.

Length frequency data for the yellow perch are presented in Fig. 50. The 0 year class and 2 year class were evident in May, June, and July, becoming less obvious in August and September. The young-of-the-year grew from a mean length of about 10 mm in May to approximately 40 mm in July. Excluding the young-of-the-year, the numbers collected monthly are fairly constant; but unlike the other species, an increased number was collected in the November and December samples. Since a majority of these fish were collected with the otter trawl from May to December, this increase either reflects the increased catchability with the seasonal decline in water temperature, or a movement from the shore zone into the deeper otter trawl sampling stations. The former explanation is more plausible since few fish of this species were collected with the beach seine in the shore zone.

In summary, various year classes of 38 different species were found within the Bush River area from March to December 1972. The early developmental stages of fishes from all three groups of spawners – freshwater, estuarine, and marine – use this tributary of the upper Bay as a common feeding or nursery area. Only two new species (the green sunfish and longear sunfish) were found to date in this study that have not been noted in the area by other researchers.

A reduction in fish numbers in early summer may have been a result of tropical storm Agnes which greatly altered normal salinities and temperatures in the upper Chesapeake Bay and its tributaries. The extension of the white perch spawning into late June and early July was noted, which may also have been caused by the change in water quality brought about by a cool, wet spring or by Agnes.

Fall sampling showed, with one exception, a general reduction in numbers. This reduction is probably attributed to the movement of fish out of the sampling areas into the deeper water of the upper bay.

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APPENDIX A

NUTRIENT ANALYSIS DATA SHEETS

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 10 JUL 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
		3	6	8	9	
Inorganic carbon		4.8	4.8	3.2	7.5	
Total Carbon						
Organic Carbon						
Nitrite-Nitrogen		0.013	0.015	0.016	0.015	
Nitrate-Nitrogen		0.70	0.87	0.98	1.08	
Ammonium-Nitrogen		0.04	0.15	0.12	0.08	
Total Unoxidized Nitrogen		0.42	0.54	0.42	0.44	
Organic Nitrogen		0.38	0.39	0.30	0.36	
Orthophosphate-Phosphorus		0.012	0.027	0.025	0.019	
Total Phosphorus		0.050	0.071	0.063	0.038	
Non-orthophosphate Phosphorus		0.038	0.044	0.038	0.019	

TABLE A-1

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 8 AUG 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
		3	6	8	9
Inorganic carbon		4.1	5.1	8.4	9.9
Total Carbon					
Organic Carbon					
Nitrite-Nitrogen		0.006	0.027	0.051	0.104
Nitrate-Nitrogen		0.27	0.57	0.87	0.86
Ammonium-Nitrogen		0.09	0.11	0.20	0.13
Total Unoxidized Nitrogen		0.57	0.63	0.54	0.46
Organic Nitrogen		0.48	0.52	0.30	0.34
Orthophosphate-Phosphorus		0.003	0.008	0.020	0.016
Total Phosphorus		0.024	0.023	0.032	0.019
Non-orthophosphate Phosphorus		0.021	0.015	0.012	0.003

TABLE A-2

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 12 SEPT 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
		3	6	8	9
Inorganic carbon		3.0	7.4	9.8	13.6
Total Carbon					
Organic Carbon					
Nitrite-Nitrogen		0.004	0.004	0.005	0.019
Nitrate-Nitrogen		0.02	0.02	0.17	0.50
Ammonium-Nitrogen		0.11	0.04	0.04	0.10
Total Unoxidized Nitrogen		0.53	0.38	0.39	0.40
Organic Nitrogen		0.42	0.34	0.35	0.30
Orthophosphate-Phosphorus		0.001	0.000	0.009	0.013
Total Phosphorus		0.013	0.010	0.023	0.042
Non-orthophosphate Phosphorus		0.012	0.010	0.014	0.029

TABLE A-3

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 24 OCT 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
	3	6	8	9	
Inorganic carbon	7.6	8.8	10.5	11.1	
Total Carbon					
Organic Carbon					
Nitrite-Nitrogen	0.008	0.012	0.023	0.027	
Nitrate-Nitrogen	0.30	0.36	0.57	0.74	
Ammonium-Nitrogen	0.09	0.08	0.08	0.09	
Total Unoxidized Nitrogen	0.60	0.46	0.34	0.32	
Organic Nitrogen	0.51	0.38	0.26	0.23	
Orthophosphate-Phosphorus	<0.001	0.001	0.001	0.004	
Total Phosphorus	0.015	0.011	0.009	0.011	
Non-orthophosphate Phosphorus	0.015	0.010	0.008	0.007	

TABLE A-4

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 21 NOV 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
		3	6	8	9	
Inorganic carbon		5.7	7.3	9.8	8.6	
Total Carbon		13.7	14.1	15.1	13.7	
Organic Carbon		8.0	6.8	5.3	5.1	
Nitrite-Nitrogen		0.011	0.007	0.011	0.012	
Nitrate-Nitrogen		0.71	0.40	0.59	0.94	
Ammonium-Nitrogen		0.18	0.05	0.11	0.13	
Total Unoxidized Nitrogen		0.51	0.24	0.26	0.31	
Organic Nitrogen		0.33	0.19	0.15	0.18	
Orthophosphate-Phosphorus		0.008	0.001	0.001	0.016	
Total Phosphorus		0.032	0.012	0.033	0.027	
Non-orthophosphate Phosphorus		0.024	0.011	0.032	0.011	

TABLE A-5

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

Site: BUSH RIVER

Date: 11 DEC 72

Concentration (ppm as the element)

Dissolved Species	Collection Station				
		3	6	8	9
Inorganic carbon		4.1	5.5	6.9	6.0
Total Carbon		8.1	8.3	9.3	6.8
Organic Carbon		4.0	2.8	2.4	0.8
Nitrite-Nitrogen		0.014	0.010	0.007	0.008
Nitrate-Nitrogen		0.87	0.82	0.78	0.95
Ammonium-Nitrogen		0.14	0.06	<0.01	0.04
Total Unoxidized Nitrogen		0.50	0.40	0.63	0.33
Organic Nitrogen		0.36	0.34	0.63	0.29
Orthophosphate-Phosphorus		0.029	0.008	0.006	0.009
Total Phosphorus		0.049	0.013	0.013	0.009
Non-orthophosphate Phosphorus		0.020	0.005	0.010	<0.001

TABLE A-6

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Perryman